P NT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
REC/52645001		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 01348	10/04/2000	19/04/1999
Applicant		
CORMON LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has be n furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] th text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comm nts to this Authority.

6. The figure of th **drawings** to be publish d with th abstract is Figure No. 1

   [X] as suggested by th applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characteriz s th invention.

   [ ] Non of th figures.

INTERNATIONAL SEARCH REPORT

International Application No
PC[redacted] 00/01348

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01N17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 4 338 097 A (TURNER MERVYN E D ET AL) 6 July 1982 (1982-07-06) column 1, line 5 - line 21 column 1, line 59 - line 64 column 2, line 4 - line 24 column 3, line 14 - line 44 column 4, line 28 - line 33	1,2,5,6, 10 3,4,9
X	US 3 155 933 A (ROHRBACK GILSON A. ET AL.) 3 November 1964 (1964-11-03) column 1, line 10 - line 13 column 1, line 59 - line 70 column 2, line 12 - line 27 column 2, line 54 - line 64 column 3, line 30 - line 51 figures 2-4	1,2,5,10

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 July 2000	10/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Stussi, E

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Interna[redacted]al Application No
PC[redacted] 00/01348

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 587 479 A (RHOADES REX V ET AL) 6 May 1986 (1986-05-06)	9
A	column 2, line 48 - line 49	1-8,10
Y	US 2 987 672 A (MARSH GLENN A. ET AL.) 6 June 1961 (1961-06-06) column 1, line 26 - line 30 column 2, line 42 - line 65 figures 1-3	3,4
A	US 5 854 557 A (TIEFNIG EUGEN) 29 December 1998 (1998-12-29) column 1, line 26 - line 30 column 2, line 25 - line 34 column 3, line 21 -column 4, line 12 column 11, line 14 - line 46	1-10
A	US 4 019 133 A (MANLEY ROBERT E ET AL) 19 April 1977 (1977-04-19) the whole document	1-10
A	US 4 703 254 A (STROMMEN ROE) 27 October 1987 (1987-10-27) the whole document	1-10
A	US 4 338 563 A (RHOADES REX V ET AL) 6 July 1982 (1982-07-06) the whole document	1-10
A	EP 0 150 552 A (SSL LTD) 7 August 1985 (1985-08-07) the whole document	1-10
A	US 5 446 369 A (BYRNE MARK T ET AL) 29 August 1995 (1995-08-29) the whole document	1-10

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/ 00/01348

Patent document cited in search report		Publication dat	Patent family member(s)		Publication dat
US 4338097	A	06-07-1982	DE	3070482 D	15-05-1985
			DK	67281 A	09-11-1981
			EP	0039750 A	18-11-1981
			NO	803865 A,B,	09-11-1981
US 3155933	A	03-11-1964	NONE		
US 4587479	A	06-05-1986	NONE		
US 2987672	A	06-06-1961	NONE		
US 5854557	A	29-12-1998	AT	401579 B	25-10-1996
			AT	76093 A	15-02-1996
			US	5583426 A	10-12-1996
US 4019133	A	19-04-1977	NONE		
US 4703254	A	27-10-1987	NONE		
US 4338563	A	06-07-1982	AU	536870 B	24-05-1984
			AU	6830081 A	18-02-1982
			BE	887924 A	14-09-1981
			CA	1177537 A	06-11-1984
			DE	3104177 A	11-03-1982
			FR	2488406 A	12-02-1982
			GB	2081904 A,B	24-02-1982
			JP	57034435 A	24-02-1982
			NL	8100123 A	01-03-1982
EP 0150552	A	07-08-1985	AU	570560 B	17-03-1988
			AU	4244685 A	21-11-1985
			DE	3476267 D	23-02-1989
			NO	851976 A	18-11-1985
US 5446369	A	29-08-1995	AU	5325094 A	09-05-1994
			WO	9409354 A	28-04-1994

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 21 December 2000 (21.12.00)	
International application No. PCT/GB00/01348	**Applicant's or agent's file reference** REC/52645001
International filing date (day/month/year) 10 April 2000 (10.04.00)	**Priority date** (day/month/year) 19 April 1999 (19.04.99)
Applicant HEMBLADE, Barry	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:
17 November 2000 (17.11.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Pascal Piriou
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 9908950.0 **Examiner:** Iwan Thomas
Claims searched: 1-10 **Date of search:** 18 January 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1N NAFG

Int Cl (Ed.7): G01N 17/00, 17/02

Other: Online: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	WO 86/02728 A1	(VIDEM) See abstract and page 2 - 4	1 & 2
A	US 4603113	(BAUER) See figs. 1 & 4, and col. 2 lines 31-65.	1 & 2
A	US 4426618	(C.I.S.E. SPA) See abstract, col. 3 lines 15-26, and col. 3 line 40 - col. 4 line 17	1
A	US 4338563	(ROHRBACK) See abstract, col. 2 line 10-26, and cols. 3 & 4.	1 & 2

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

BOULT WADE TENNANT
Verulam Gardens
70 Gray's Inn Road
London WC1X 8BT
GRANDE BRETAGNE

RECEIVED
21 MAY 2001
BOULT WADE TENNANT

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

	Date of mailing *(day/month/year)* 18.05.2001
Applicant's or agent's file reference REC/52645001	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01348	10/04/2000	19/04/1999

Applicant
CORMON LIMITED et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Conner, M Tel.+49 89 2399-2241

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
REC/52645001		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01348	10/04/2000	19/04/1999
International Patent Classification (IPC) or national classification and IPC G01N17/00		
Applicant CORMON LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
17/11/2000	18.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Stussi, E Telephone No. +49 89 2399 2265

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01348

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-17	as originally filed

Claims, No.:

1-10	as originally filed

Drawings, sheets:

1/3-3/3	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	3,4,7,8,9
	No:	Claims	1,2,5,6,10
Inventive step (IS)	Yes:	Claims	
	No:	Claims	3,4,7,8,9
Industrial applicability (IA)	Yes:	Claims	1-10
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Comments on Section V

Reference is made to the following documents:

D1 = US-A-4338097
D2 = US-A-3155933
D3 = US-A-4019133
D4 = US-A-2987672

1. The document D1 is regarded as being the closest prior art to the subject-matter of claim 1, and discloses the following features in combination (the references in parentheses applying to this document):
apparatus for monitoring the effect on a material of exposure to a fluid (col.1, ll.5-13), said apparatus comprising a sensor element formed as a ring of the material (col.2, ll.19-21), wherein said ring is mounted coaxially in a section of the pipe for carrying said fluid (fig. 1), so as to be exposed to said fluid (col.1, ll.59-64), and is electrically insulated from said pipe (col.3, ll.14-29), and means for monitoring changes in electrical resistance in said ring sensor element (col.4, l.28 to col.5, l.24).

   Therefore, the subject matter of claim 1 lacks novelty (Art. 33(2) PCT).

2. It is additionally noted that the subject matter of claim 1 lacks novelty also with respect to document D2, cf. in particular col.1, ll.59-70, col.2, ll.12-27, ll.54-57 and ll.60-63 and col.3, ll.30-51.

3. Dependent claims 2-10 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, the reasons being as follows:

3.1 The additional features of claim 2 are known from D1, cf. reference element 7b in fig. 2.
The same objection holds for the additional features of claim 5 (cf. D1, col.3, ll.38-41), claim 6 (cf. D1, col.4, ll.28-32) and claim 10 (cf. D1, col.2, ll.19-21).

3.2 The additional features disclosed in claims 3 and 4 have already been employed

for the same purpose in a similar apparatus, see document D4, figs 1-3 and col.1, l.1-30 and col.2, l.42-65. It would therefore be obvious to the person skilled in the art, to apply these features with corresponding effect to an apparatus according to document D1, thereby arriving at an apparatus according to claims 3 and 4.

3.3 In claim 7 a slight constructional change in the apparatus of claim 3 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen.
A similar objection holds for the subject matter of claim 8.

3.4 The additional feature of claim 9 is described in document D3 as providing the same advantages as in the present application (cf. D3, strain gauge 128 and col.2, ll.48-49). The skilled person would therefore regard it as a normal design option to include this feature in the apparatus described in document D1 in order to solve the problem posed.

Comments on Section VII

1. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1 and D2 is not mentioned in the description, nor are these documents identified therein.

Comments on Section VIII

Claim 1 is not supported by the description as required by Article 6 PCT, as its scope is broader than justified by the description and drawings. In fact the whole application including the title relates to the detection of corrosion, whereas claim 1 is so broadly formulated that other phenomena could be included (e.g. in a gas sensor the transducing element, e.g. tin oxide, is also a material affected by a fluid).

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01N 17/00	A1	(11) International Publication Number: WO 00/63674
		(43) International Publication Date: 26 October 2000 (26.10.00)

(21) International Application Number: PCT/GB00/01348

(22) International Filing Date: 10 April 2000 (10.04.00)

(30) Priority Data:
9908950.0 19 April 1999 (19.04.99) GB

(71) Applicant *(for all designated States except US)*: CORMON LIMITED [GB/GB]; Cormon House, Riverbank Business Centre, Old Shoreham Road, Shoreham–by–Sea, West Sussex BN43 5FL (GB).

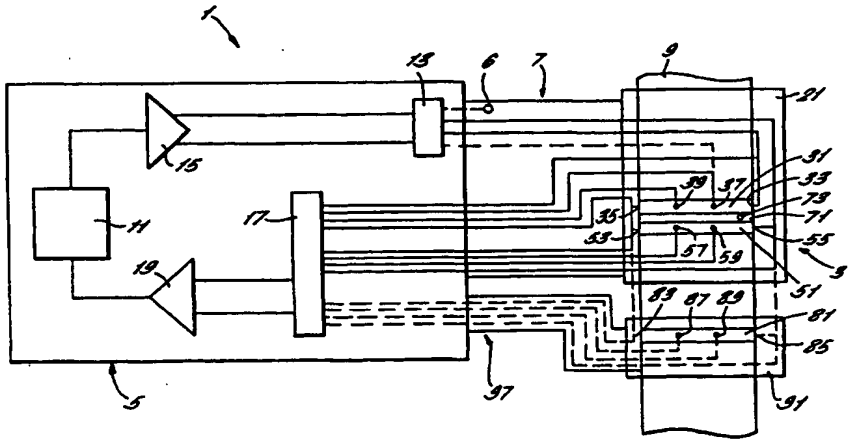
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: HEMBLADE, Barry [GB/GB]; 49 Lawrence Road, Hove, West Sussex BN3 5QE (GB).

(74) Agent: BOULT WADE TENNANT; Verulam Gardens, 70 Gray's Inn Road, London WC1X 8BT (GB).

(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: ELECTRICAL RESISTANCE SENSOR AND APPARATUS FOR MONITORING CORROSION



(57) Abstract

An apparatus (1) is disclosed for monitoring the effect on a material of exposure to a fluid, and thereby monitoring the effect on a section of pipe (9) for carrying the fluid. The apparatus comprises a sensor element (51) exposed to the fluid and formed as a ring of the material coaxially mounted within, but electrically insulated from, the section of pipe (9). Changes in the electrical resistance of the sensor element (51) are monitored. Preferably, the apparatus also comprises a reference element (31) electrically insulated from the pipe (9), electrically connected in series to the sensor element (51) and protected from exposure to the fluid. The elements may both be made from the same material as the pipe (9) and, as they are contained within it, experience the same temperature and pressure variations as the pipe (9). In this manner a change in the resistance of the sensor element (51) caused by corrosion/erosion by the fluid accurately indicates the degree of corrosion/erosion of the pipe (9) carrying the fluid.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
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EE	Estonia	**LR**	Liberia	**SG**	Singapore		

ELECTRICAL RESISTANCE SENSOR AND APPARATUS FOR MONITORING CORROSION

FIELD OF THE INVENTION

The present invention relates to electrical resistance corrosion sensors for detecting and monitoring loss of material due to corrosion and/or erosion caused by the interaction of that material with its environment. More specifically, the present invention relates to electrical resistance corrosion sensors for monitoring corrosion and/or erosion of the internal surface of a pipe through which a fluid environment flows.

BACKGROUND OF THE PRIOR ART

Corrosion sensors are used in the detection and monitoring of loss of material, such as the internal surface of a pipeline wall, due to corrosion and/or erosion from interaction between the material and the environment in contact with the material. Such conditions exist in oil or gas pipelines.

Commonly, corrosion sensors use electrical resistance methods to detect loss of material due to corrosion/erosion. Such a corrosion detector system includes using the principles of electrical resistance to determine corrosion/erosion of a pipeline wall surface. Such a system consists of measuring the thickness of the pipeline wall with pick-up points along the external surface of a pipeline section. The pipeline section is energised by a longitudinal current applied at two points adjacent to either side

of the pick-up area. The current density map through the material, proportional to wall thickness, is derived by measurement of voltages across the matrix of pick-up points relative to an external reference, and the resistive ratios are converted into the metal loss.

The sensitivity of such prior art corrosion detector arrangements is limited by various factors. For instance, the sensitivity of the corrosion detector arrangement is dependant on the maximum current which can be sustained. The maximum current is limited for intrinsically safe applications in potentially explosive environments such as in oil and gas pipelines. In such corrosion detector systems, sensitivity is also limited by the very small measured resistive voltages between array pick-up points. Disturbances such as noise and dc offsets occurring in the electronic circuitry of the corrosion detector systems and thermoelectric voltages and electromagnetic noise in the leads make high-resolution measurements of such small voltages difficult.

Additionally, changes in the temperature in the environment in which pipeline is situated changes the electrical resistance of the pipe. For example, the resistance of steel may change by 0.4% per °C. In electrical resistance corrosion monitoring systems configured with an element having an exposed surface to the environment and a reference system external to the environment such as the pipeline fluid environment, changes in fluid temperatures

significantly limit the accuracy and sensitivity of the monitoring system if the temperature of the pipeline and external reference system differ. To illustrate, a nominal difference in temperature of 0.25C° between the pipeline and reference system will cause a change in the resistance ratio of 1000ppm.

Furthermore, the circumferential and radial temperature excursions may be present around the profile of the pipeline. This will depend on the pipeline process fluid conditions and the location of the pipeline itself. For example, the fluid environment may comprise a cross-sectional layered profile of water, crude oil, and gas. The boundary phases between these layers may also change over time. A difference of 0.25°C between the top and bottom of the pipeline would cause a further change in the resistance ratio of about 1000ppm.

The hydrostatic and thermal stresses induced in pipeline structures will also influence the measured resistive voltages. In prior art corrosion detector arrangements with a reference system external to the fluid environment, the reference system will not be subjected to the hydrostatic and thermal loads and therefore further errors will occur.

The mechanisms involved in the change of resistance due to strain are extremely complex and not easily predicted. Change in resistance due to strain relates to the distortion of the lattice structure, which varies according to material composition and microstructures. Although the affects are much less than temperature, typical pipeline steels exhibit

changes of between 2000-4000ppm per 100 BAR of pressure or 20-40ppm per BAR. Of course, in prior art corrosion monitoring with an external reference system, the external reference system is not subject to the changing internal pressure of the pipeline and the external reference system is not subject to the resultant changing resistive voltages. This contributes to further errors.

Similarly, as temperature change occurs there will be subsequent residual thermal stresses induced, resulting in further change in the resistive voltages. In addition, it is apparent that under a pressurised system the change in wall thickness due to corrosion and/or erosion will result in an increase in radial and circumferential stress distributions through the pipe wall. This will in turn induce further unwanted change to the measured resistive voltages.

The cumulative effect of resistive voltage changes due to changes of in process conditions not adequately compensated by the referencing system could result in expected deterioration of resolutions in excess $\pm$ 4000ppm, for a temperature difference between pipeline and external reference system of 1°C and a pressure difference of 100BAR. With additional errors expected due to profile temperature and stress effects.

Therefore, there is a need for an electrical resistance corrosion monitor with a greater sensitivity to accurately measure at a higher resolution, the corrosion and/or erosion of a pipeline in a corrosive/erosive environment, especially where

the environment temperature and/or hydrostatic pressure may be fluctuating.

SUMMARY OF THE INVENTION

The present invention provides apparatus for monitoring the effect on a material of exposure to a fluid, said apparatus comprising a sensor element formed as a ring of the material, wherein said ring is mounted coaxially in a section of pipe for carrying said fluid, so as to be exposed to said fluid, and is electrically insulated from said pipe, and means for monitoring changes in electrical resistance in said ring sensor element.

An embodiment of the invention provides the ability to measure the internal corrosion/erosion profile of an exposed sensor ring adjacent to a co-axially spaced electrically insulated reference ring whereby current injection is applied at diametrically opposite positions and measured voltages are a function of the circumferential position.

Embodiments of the sensor arrangement provide sensor elements that possess geometric, physical dimensional, metallurgical and dynamic similarity to that of the monitored pipeline. The ring sections may be formed from actual pipeline material to act as the corroding/eroding sensor ring exposed element and compensating reference ring. In this manner, the sensing exposed ring and reference ring possess virtually identical metallurgical and microstructural properties of the pipeline material influenced by material grade and fabrication process, and ensures

identical potential corroding material and closely matching coefficients of resistivity, especially due to temperature and strain. The ability to subject the sensing and reference rings to substantially identical or similar pipeline process loading conditions that include changing environment temperatures, stresses including hydrostatic and thermal stress distributions, flow regimes including laminar/turbulent boundary layer effects/heat transfer conditions, and the electrochemical environment, facilitate realistic simulation of the actual pipeline corrosion/erosion interface.

Embodiments of the invention further provide the ability to compensate for nominal and circumferential profile temperature and stress distribution effects by an in-situ adjacent co-axially spaced electrically insulated and corrosion/erosion protected reference ring to closely match the coefficients of resistance of the sensing and reference rings.

Another embodiment of the invention further provides a compound ring comprising two rings with an exposed ring mounted in and strengthened by a back-up ring with an electrically insulating barrier between the expose ring and the back-up ring. In this embodiment, the back-up ring provides structural support for the exposed ring, which may be relatively thinner than the reference element to provide additional resolution whilst maintaining required strength to the thinner exposed element.

DESCRIPTION OF THE DRAWINGS

Examples of embodiments of the present invention will now be described with reference to the drawings in which:-

Figure 1 shows a block circuit diagram of an embodiment of the invention;

Figure 2 shows a cross-sectional view of an exposed element of an embodiment of the invention;

Figure 3 shows a cross-sectional view of a reference element of an embodiment of the invention;

Figure 4 shows a block diagram of the electrical connection point configuration of the reference element and exposed element of an embodiment of the invention; and

Figure 5 shows a cross-sectional view of another embodiment of the sensor elements.

DETAILED DESCRIPTION

A corrosion sensor 3, which is used in a corrosion monitoring system 1 for monitoring corrosion in an environment such as a pipeline 9, is shown in Figure 1. The corrosion monitoring system 1 generally comprises a sensor assembly 3 comprising a housing 21 for a reference element 31 and an exposed element 51, electronic circuitry 5 and a cable 7 for connecting the electronic circuitry to the sensor assembly 3.

The exposed element and the reference element are electrically connected in series and connected to a current generator 11,15 which drives current through the series circuit. The elements are connected to the electronic circuitry at pick-off points, e.g. points 33,35,53,55. The points define two portions on each

of the sensor elements for the current to flow through. The electronic circuitry further comprises voltage monitoring means 11,19 arranged to monitor the voltage developed across each of the regions defined by the points of the exposed and reference elements.

In preferred embodiments discussed in further detail below, the electronic circuitry further includes a current multiplexer 13 for alternately switching the current supplied to different points on the exposed and reference elements, and a voltage monitoring multiplexer 17 for switching the serial link electrically connecting the elements, and also for the voltage monitoring means to measure alternately the voltage across each element.

In an embodiment of the invention, each of the elements 31,51 of the sensor arrangement 3 have a closed-ring configuration. The reference closed-ring element 31 is electrically connected in series with the exposed closed-ring element 51. Conveniently, the sensor in any of the embodiments may be constructed to fit any pipeline that is to be monitored for corrosion/erosion. The exposed element and the reference element may be formed from adjacent sections or slices of the pipeline. This construction of the sensor elements ensures that the sensor elements are near to identical as possible including the material coefficient of resistivities. The process by which the slices are formed is preferably a process that minimises change to the microstructure of the material both local to and remote from the edges of the elements, and may for example include spark machining,

wire corrosion, etching and the like. Each section or slice of the pipeline is preferably in the range of 8mm - 12mm wide. The thickness of the elements 31,51 are determined by the dimensions of the pipeline.

Conveniently, of course, in embodiments of the invention the sensors elements may be formed from a material different than the material of the actual pipeline material. For example, if the corrosion/erosion effects from the pipeline environment are to be monitored for a material different to that of the material of the pipeline the corrosion sensor is mounted, then the sensor elements may be for example, formed from sections or slices of another pipeline of the material of interest. Of course, in this embodiment the pipeline that the sensor elements are formed from may have similar dimensions as the pipeline the sensor is to be mounted in.

The elements maintain the radial orientation when mounted in the sensor. As shown in Figures 2 and 3, orientation marks 45,65 are provided on the elements which are aligned when mounted in the sensor 3. The orientation marks are made prior to parting of the elements from the pipeline material. The elements 31,51 are co-axially spaced and separated by a spacer ring 71. The spacer ring is coated with an insulating material such as epoxy resin or ceramic or the like. The material of spacer ring may form part of the housing 21 and the material of the spacer ring may also insulate the elements 31,51 from the pipeline when the sensor is mounted in the pipeline 9.

Each ring element 31,51 consists of additional co-planer pick-off points equally spaced around the outer circumference of the ring. The pick-off points are formed typically by spot welding, i.e. localised heat treatment to minimise any disturbance to the resistive properties of the elements. For example, each ring comprises four such points in addition to points 33,35,53,55 as discussed above for connecting the sensor elements to the electronic circuitry 5, however, embodiments of the invention do not necessarily require additional points and fewer or more than four additional points may be used.

The pick-off points in this example define three regions on each portion of each element. On the reference ring element 31 pick-off points 37,39 define three sectors on the upper portion of the reference element and pick-off points 41,43 define three sections on the lower portion of the reference element. Similarly, on the exposed ring element 51 pick-off points 57,59 define three sections on the upper portion of the exposed element and pick-off points 61,63 define three sectors on the lower portion of the exposed element. Of course, although six points on each of the elements are described with reference to this embodiment, any number of pick-off points may be used. The number of points chosen depends on the granularity of sectors required.

Referring to Figure 4, a current input I_{in1} is shown at a position A at pick-off point 33 of the reference ring element 31 and a current output I_{out1} is shown at position B at pick-off point 55 of the

reference ring element 51. In this arrangement, the elements are electrically connected at points 35 and 53 via multiplexer 17 for example, and position A and B of the elements are electrically connected to the current multiplexer 13.

A second current input I_{in2} is shown at a position C at point 37 and a second current output I_{out2} is shown at a position D at point 43 of the reference ring element. Similarly, a third current input I_{in3} is shown at a position E at point 57 and a third current output I_{out3} is shown at a position F at point 43 of the exposed ring element. In this arrangement, the ring elements are electrically connected as shown at position D and E from points 43 and 57 via multiplexer 17 for example, and the position C and B are electrically connected to the current multiplexer 13.

In this configuration, the current multiplexer 13 allows for selectively and alternately switching the current supplied to the different points A-B or C-F and simultaneously the multiplexer 17 for example may switch the linking points 35-53 or 43-57, respectively, on the exposed and reference elements and provides for a selectable dual position current generator which drives the current through the series circuit. The second current input position C is adjacent to a sector pick-off position A. Of course, other configurations may be provided having different current connecting points.

Similarly, in this embodiment, each of points 33,37,39,35,41,47 of the reference element and each of points 53,57,59,55,63,61 of the exposed element may be

connected to the voltage monitoring multiplexer 17 for switching the voltage monitoring means to measure alternately the voltage across each sector defined by the points. The multiplexer is provided for switching the voltage monitoring positions across each ring and the voltages for each sector.

With reference to Figures 1 and 4, the operation of the sensor generally involves measuring the voltages across each sector on each of the elements, switching the drive current position and measuring the voltages with the new drive current position. In this configuration, there are six sectors on each ring, however, as discussed above, the number of sectors chosen may differ, i.e. more or fewer points may be selected. The resistance ratio of each sector is determined from the voltages developed across each sector. For the exposed element R_s, sector Ra is defined by points 53,57 which is indicated as 0°-60°, sector Rb is defined by points 57,59 which is indicated as 60°-120°, Rc is defined by points 59,55 which is indicated as 120°-180°, Rd is defined by points 55,63 which is indicated as 180°-240°, Re is defined by points 63,61 which is indicated as 240°-300°, and Rf is defined by points 61,53 which is indicated as 300°-360° of the exposed ring element. Sectors of the reference element are similarly identified, where sector R_ra is defined by points 33,37 indicated 0°-60°, sector R_rb is defined by points 37,39 indicated 60°-120°, R_rc is defined by points 39,35 indicated 120°-180°, R_rd is defined by points 35,43 indicated 180°-240°, R_re is defined by

points 43,41 indicated 240°-300°, and $R_r f$ is defined by points 41,33 indicated 240°-300° of the reference ring element.

The ratio of resistance of the elements R_s/R_r is first determined and the exposed element ratios Ra/Rb, Ra/Rc, Rf/Rd, Rf/Re are measured along with the reference element ratios $R_r a/R_r b$, $R_r a/R_r c$, $R_r f/R_r d$, $R_r f/R_r e$.

In this configuration the current multiplexer 13 then switches the drive current position switch to current input position C and current output position F. At this time, the points electrically linking the elements serially, are switched by multiplexer 17 for example from points 35,53 to points 43,57, as shown by a dashed line in Figure 1, D-E. In this arrangement, the current input, current output, and the electrical connection between the elements rotates by 60 degrees.

The resistance ratios Ra/Rf and $R_r a/R_r f$ are then measured. Both the element R_r,R_s profiles may then be derived and profile in terms of Ra/Ra, Ra/Rb, Ra/Rc, Ra/Rd, Ra/Re and Ra/Rf, and $R_r a/R_r a$, $R_r a/R_r b$, $R_r a/R_r c$, $R_r a/R_r d$, $R_r a/R_r e$ and $R_r a/R_r f$, respectively. Then, the R_s profile is modified from the R_r profile by the equation:

$$Ra/Rb=(T-xb)/(T-xa),$$

where T=ring thickness, xa=metal loss in sector a, and $x1+x2=2T(1-1/(R_s/R_r))$, where x1=effective metal loss of upper section of the ring element, x2=effective metal loss of lower section of the ring element. Similarly, the metal loss in each other sector may be determined. In an embodiment of the invention, a

pressure sensor 73 that is commercially available may be positioned through an access hole in the spacer ring. In other embodiments the spacer ring 71 may also provide access for other monitoring devices such as electrochemical noise and linear polarisation resistance devices, and the like. For example, under typical load conditions, the pressure may be measured using the pressure sensor. Conveniently, the pressure readings, for example, may be used to calculate and eliminate changes caused by hydrostatic pressure effects.

In another embodiment, the sensor arrangement also provides the facility to monitor a number of independent sampled rings within one system, as shown in Figure 1. An additional exposed element 81 is provided as part of the sensor 3. Additional element 81 may be formed in the same manner as the exposed element 51, as discussed above. The additional element 81 may comprise an additional housing 91 and cable 97 that electrically connects pick-off points, e.g. 83,87,89,85, to the voltage monitoring means multiplexer 17. Of course, the multiplexer 17 may also link the additional element 81 serially with the other elements in a similar manner as discussed above to provide a switching capability between linking points on the additional element linking to the other elements via the multiplexer. The additional element 81 enables comparative corrosion/erosion monitoring studies or trials of different materials or grades of material, such as welded sections, evaluation of new materials against existing materials, specially

prepared or coated materials and the like. Additionally, the concurrent monitoring of identical samples is possible, thereby increasing data integrity, reliability and certainty.

In another embodiment, the sensor may comprise two or more pairs of reference and exposed elements. The pairs of elements may be electrically connected via multiplexing in a similar manner as discussed above. Providing an additional pair or pairs of reference element and exposed element allows for accurate corrosion/erosion monitoring. Thus, the number of pairs of rings is not limited to a single pair of rings.

In another embodiment of the sensor as shown in Figure 5, the exposed element may be formed from two rings with an exposed ring 101 mounted in and strengthened by a back-up ring 115 with an electrically insulating barrier 45 between rings 115,101 to form a compound sensor ring 100. The compound ring exposed element 101 may be electrically connected in a similar manner to the reference element 31, as the exposed element 51 is electrically connected to the reference element 31, as discussed above, and the pick-off point elements may be electrically insulated from the back-up ring. The exposed element is preferably formed from the same material as the reference element, for example, adjacent slices or sections of a piece of pipeline. As discussed above, this ensures that the sensor elements possess substantially identical geometric, physical, metallurgical and dynamic similarities to

each other as well as the pipeline. Of course, the elements do not necessarily need to be formed from the pipeline that the sensor will be mounted in, rather the elements may be formed from a pipeline of different a material, as discussed above. The back-up ring does not necessarily need to be the material of the pipeline and may be a material that provides greater strength for supporting the exposed element under fluid environment pressures and conditions. Additionally, if the back-up ring is of a material that is an electrically insulating material, the exposed ring and pick-off point elements may be in direct contact with the back-up ring.

In this embodiment, the back-up ring 115 provides structural support for the exposed ring, which may be relatively thinner than the reference element. In this embodiment the exposed element may have for example have any thickness that is less than thickness of the reference element. As the reference element and the exposed element are slices of the same pipeline, both share substantially the same thickness. Therefore, it is preferred to thin the element to a desired thickness by such means as wire erosion or spark erosion and the like. The compound ring may be formed by mounting within the reference element 31, where the elements may be formed from the same slice or section of pipeline and thinned with a layer of insulating material 45 separating the elements, however this may need further structural support. The exposed element 101 may be electrically connected together in series with the reference element 31, and

both elements are electrically insulated from the pipeline, as described above. The back up element may be the reference element and the pick-off points on the exposed element 103,107,109,105,113,111 are radially aligned, coaxially adjacent and insulated from the points on the reference element. The points on the exposed element 101 are connected to the multiplexer and are each insulated from the reference element. As described above, connections are made to the current multiplexer 13 for switching the current through different points or portions as shown in Figure 4, and the points linking the elements in series are connected via the multiplexer 17, for example. Embodiments of this two compound ring configuration provides additional resolution whilst maintaining required strength to the thinner exposed element.

Further modifications to the embodiments described herein will be apparent to those skilled in the art.

CLAIMS:

1. Apparatus for monitoring the effect on a material of exposure to a fluid, said apparatus comprising a sensor element formed as a ring of the material, wherein said ring is mounted coaxially in a section of pipe for carrying said fluid, so as to be exposed to said fluid, and is electrically insulated from said pipe, and means for monitoring changes in electrical resistance in said ring sensor element.

2. Apparatus as claimed in Claim 1 further comprising a reference element, said reference element being formed also as a ring, mounted coaxially in said pipe section and insulated therefrom, said second ring element being protected from exposure to said fluid.

3. Apparatus as claimed in claim 2, wherein said sensor and reference elements each comprise at least one pair of diametrically opposed electrical connection points.

4. Apparatus as claimed in claim 3, wherein each of said elements comprises a predetermined number of pairs of diametrically opposed connection points, said connection points on each element being regularly spaced around the respective ring.

5. Apparatus as claimed in either of claims 3 or 4, wherein said sensor and reference element are connected in series by respective pairs of said

diametrically opposed connection points, and said means for monitoring is arranged to determine the ratio of the resistances of said elements.

6. Apparatus as claimed in claim 5 as dependent on claim 4, wherein said means for monitoring is arranged to drive a current through said series connected elements and to pick off voltage values from the various connection points.

7. Apparatus as claimed in claim 6, wherein said monitoring means is arranged to make at least one further set of measurements by reconnecting the elements in series by different pairs of diametrically opposed connection points, driving a current through the series connected elements and picking off a further set of voltage values from the various connection points.

8. Apparatus as claimed in any of claims 2 to 7, wherein said elements are coaxially spaced apart by a spacer ring.

9. Apparatus as claimed in Claim 8, wherein said spacer ring comprises a pressure sensor.

10. Apparatus as claimed in any preceding claim, wherein at least said sensor element comprises a section cut from said pipe.

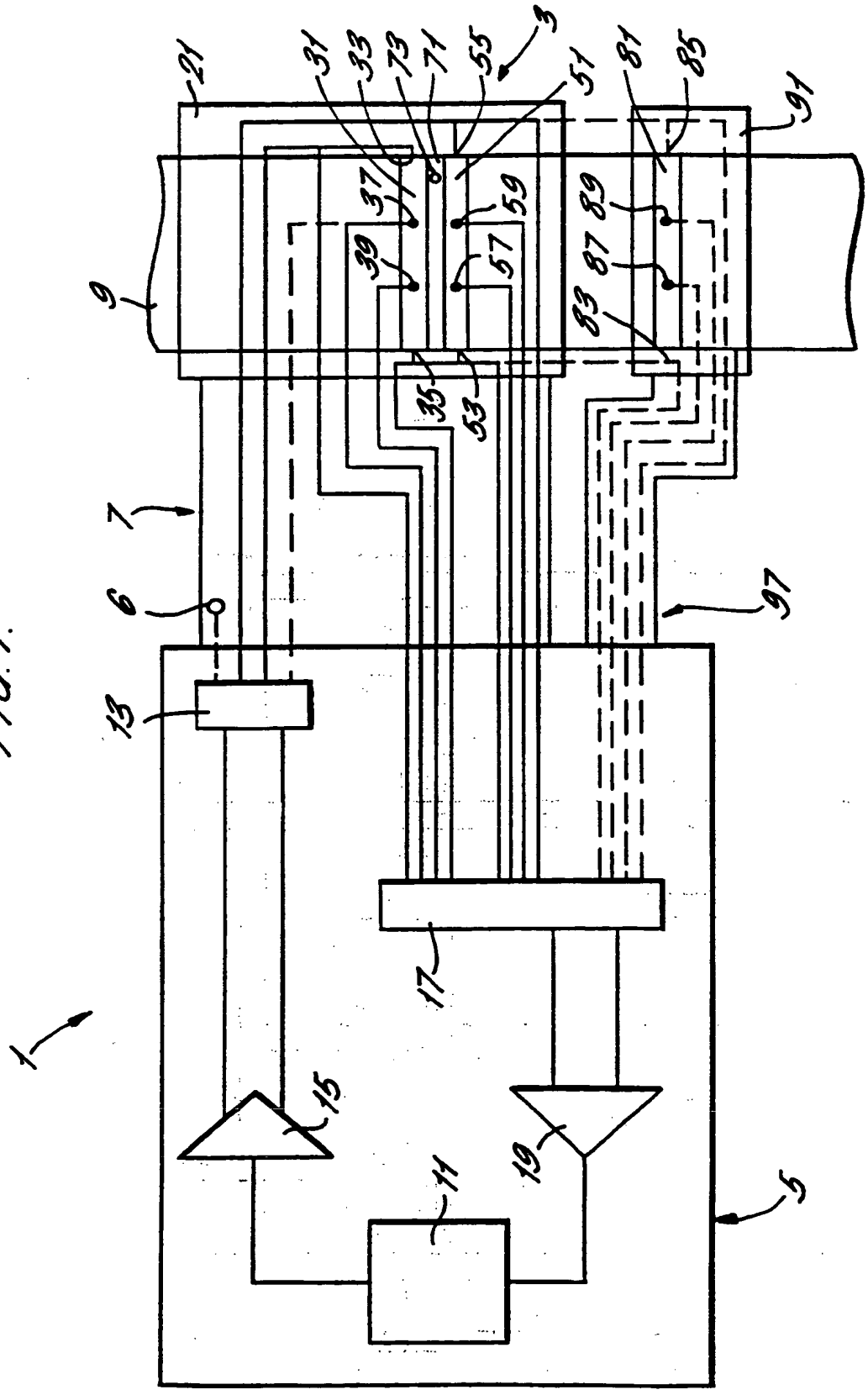
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FIG. 1.

FIG. 2.

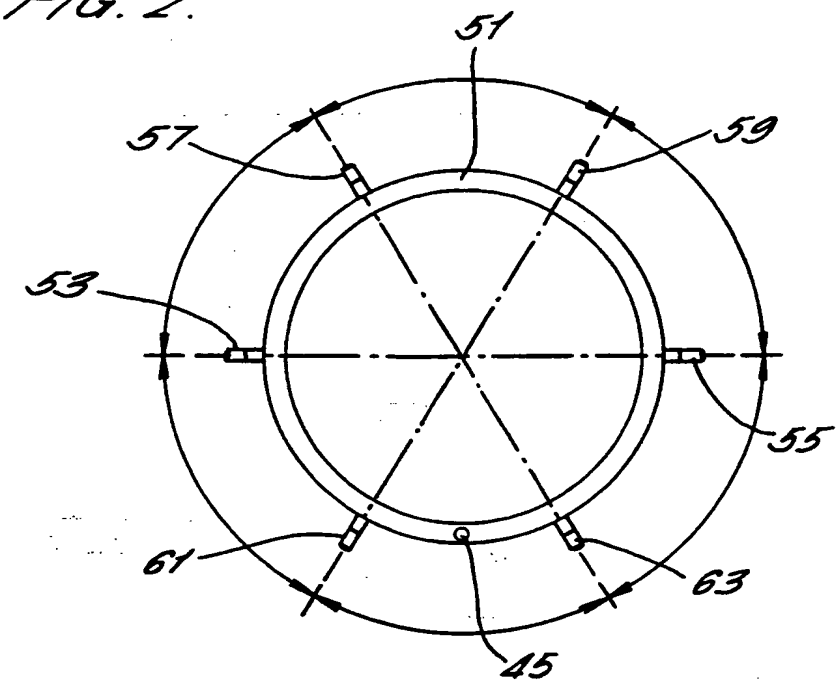

FIG. 3.

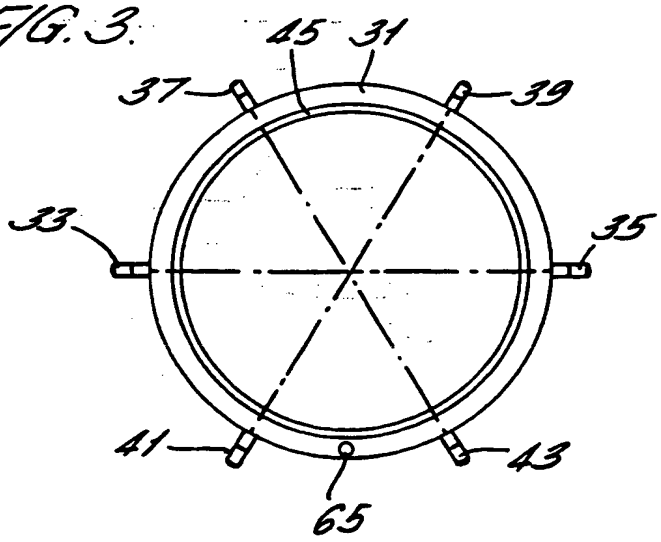

FIG. 4.

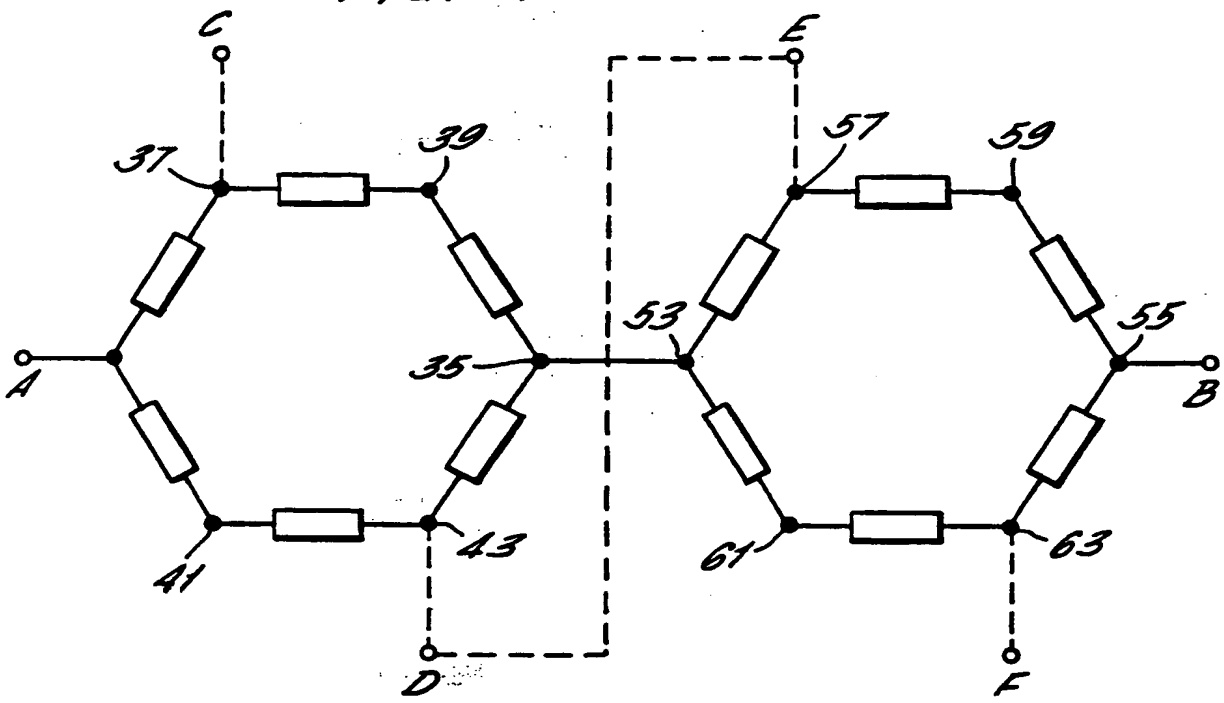
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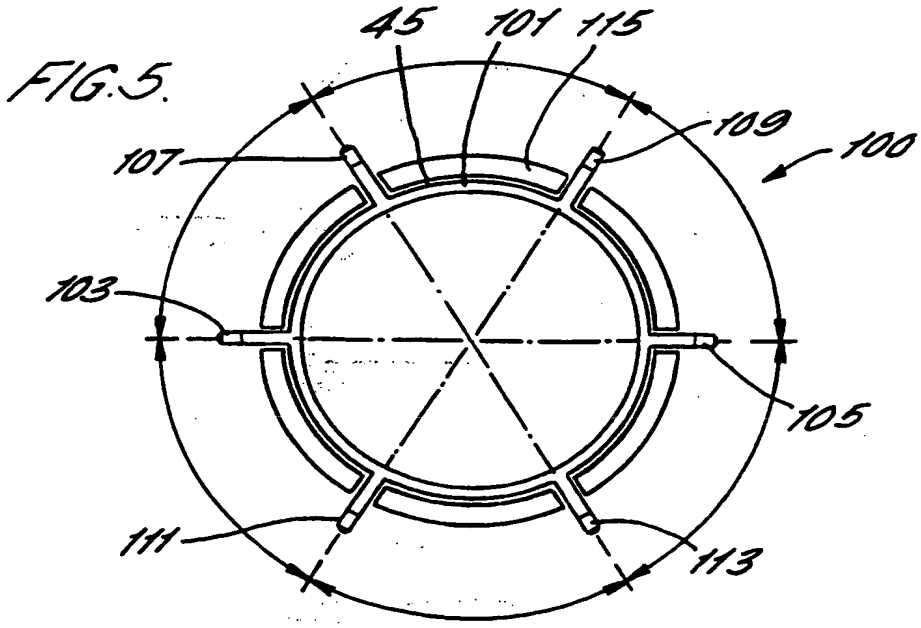
FIG. 5.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INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 00/01348

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01N17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 July 2000	10/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Stussi, E

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INTERNATIONAL SEARCH REPORT

Inter nal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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